An Online Neutron Detection System for Electron Storage Rings

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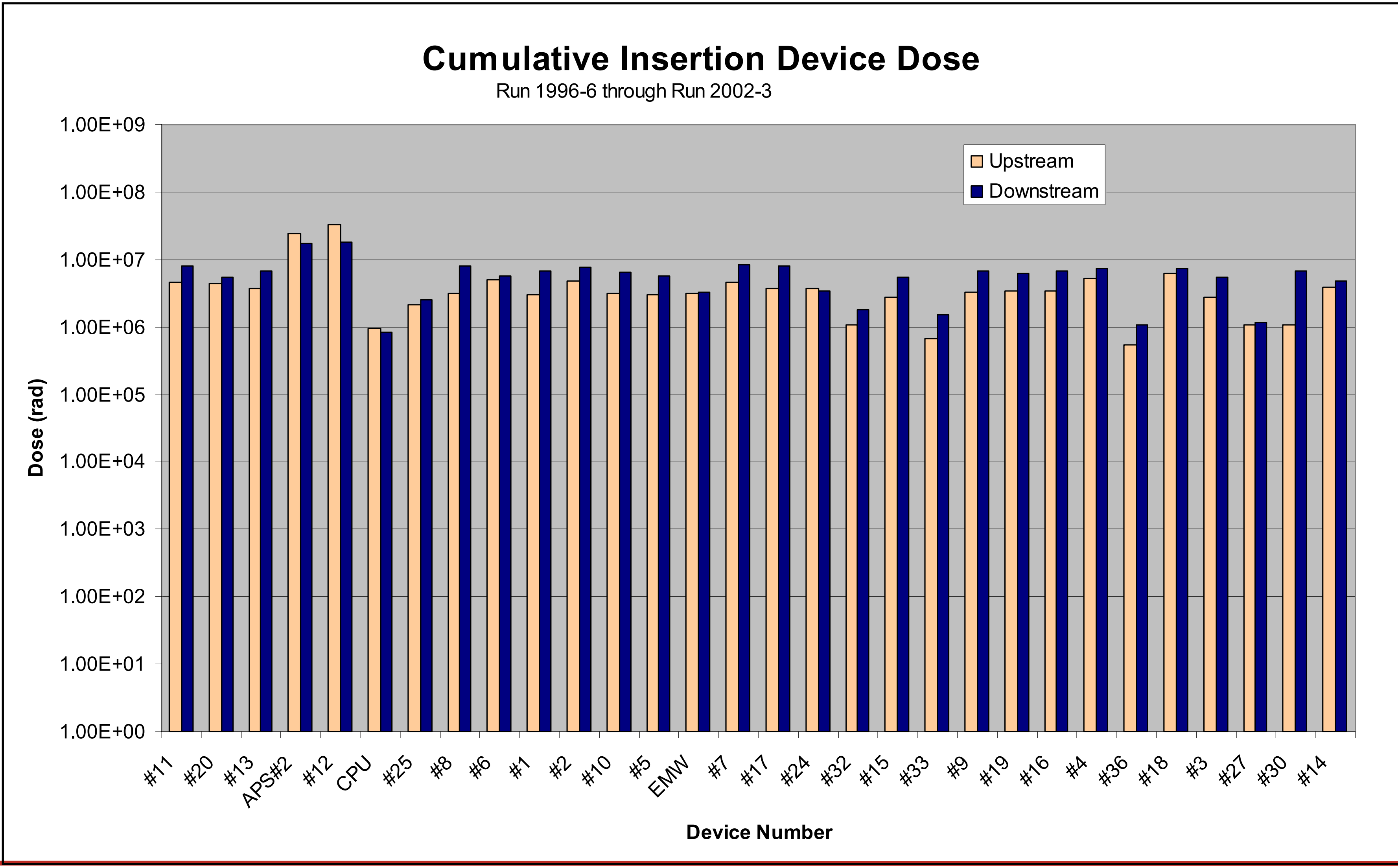
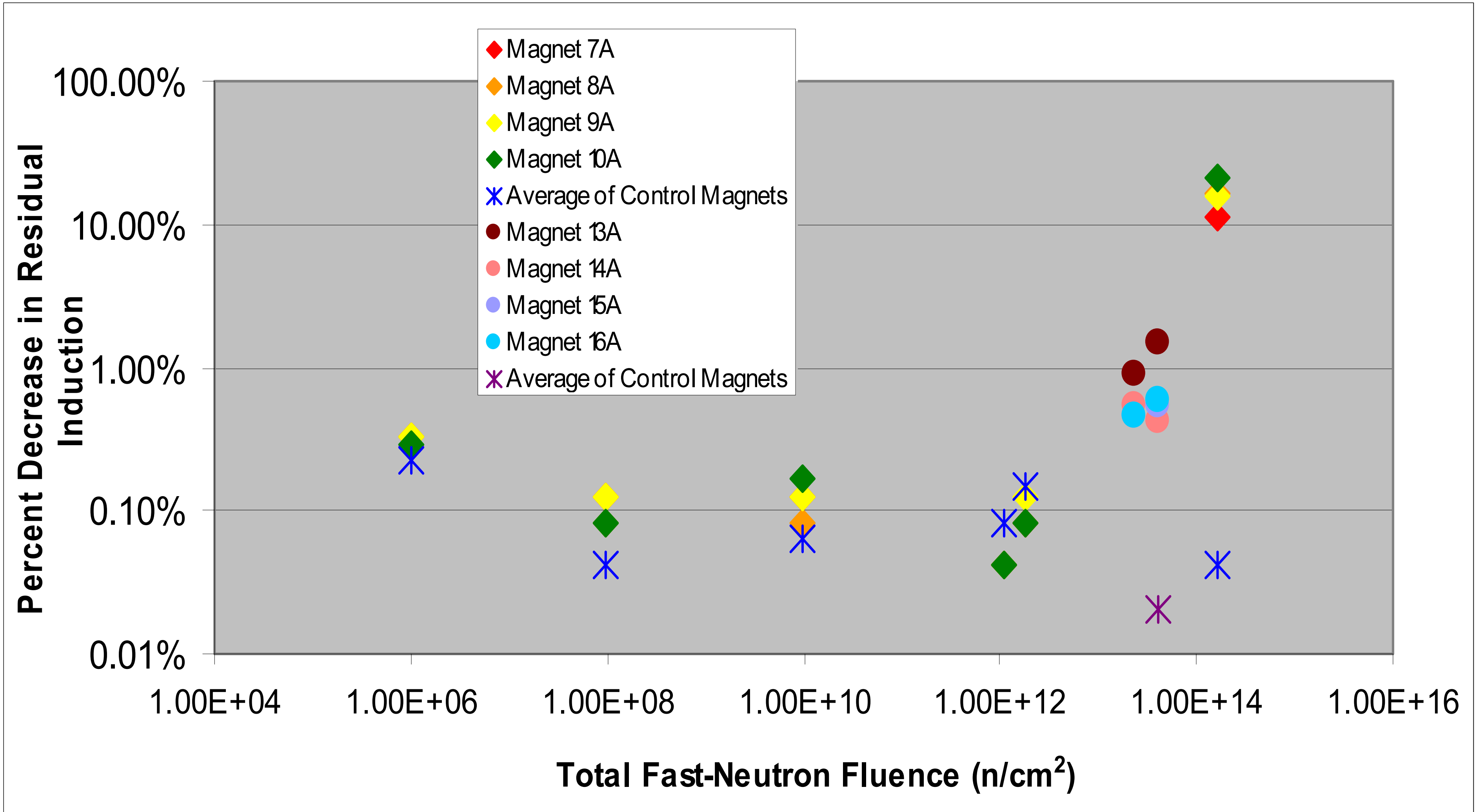
- Neutron Damage to Storage Ring Components
- Beam Loss and Neutron Production
- Fission Detectors: A Unique Advantage
- Calibration of the Fission Detectors
- Results and Discussion

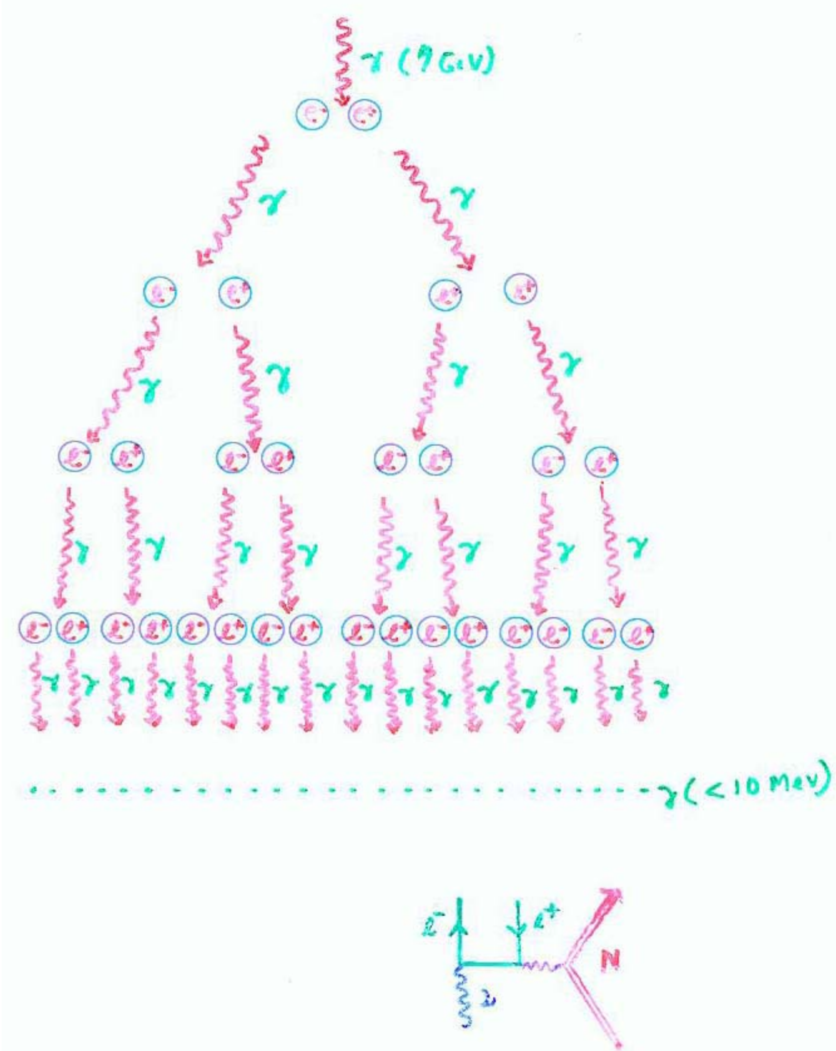
Insertion Device Cumulative Dose Results



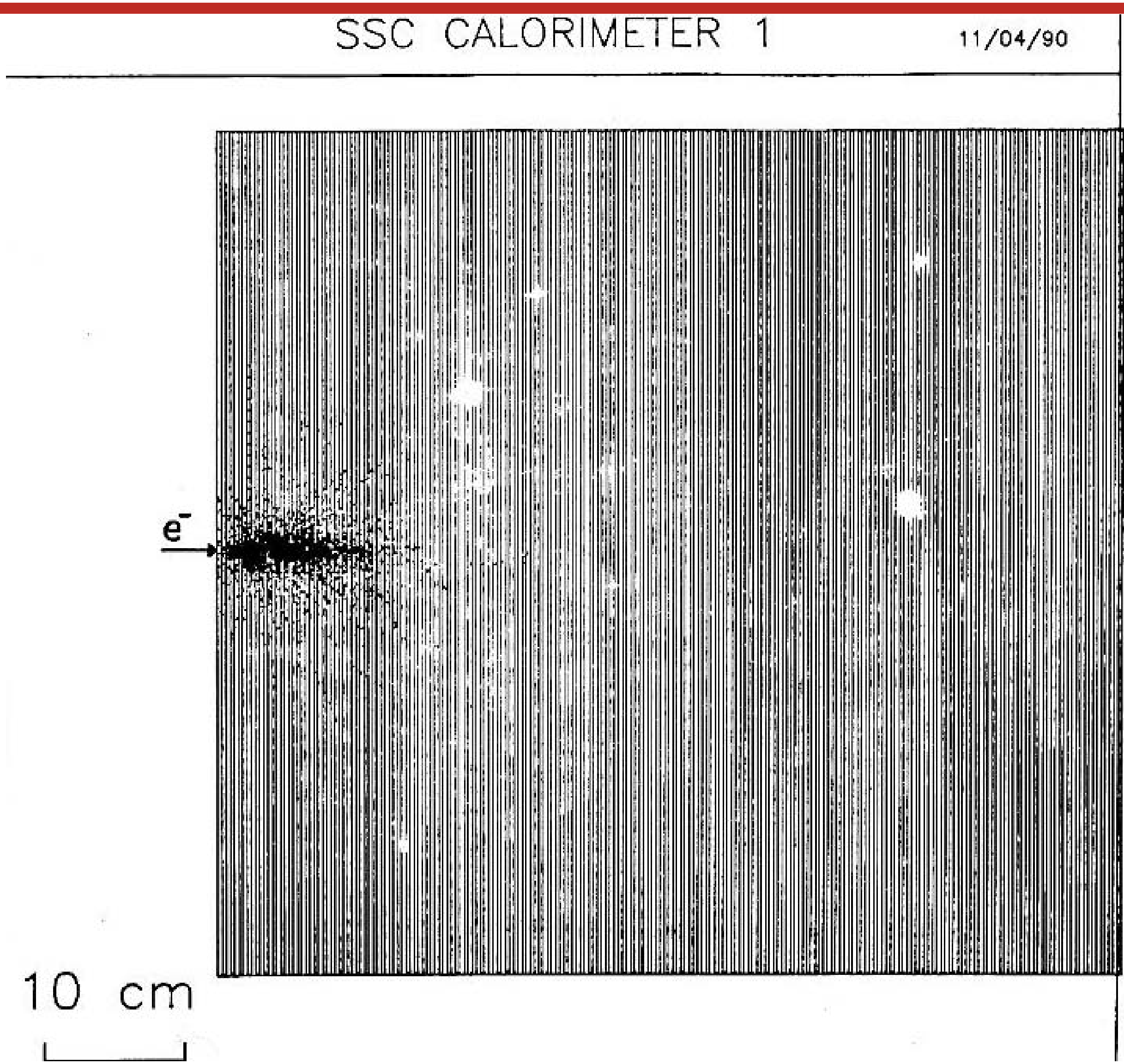
Results of Sample Magnet Irradiation



Electromagnetic Shower



Electromagnetic Shower in Pb (EGS4 Simulation)



Photon Cross Sections for C and Pb

Contributions to Photon Cross Section in Carbon and Lead

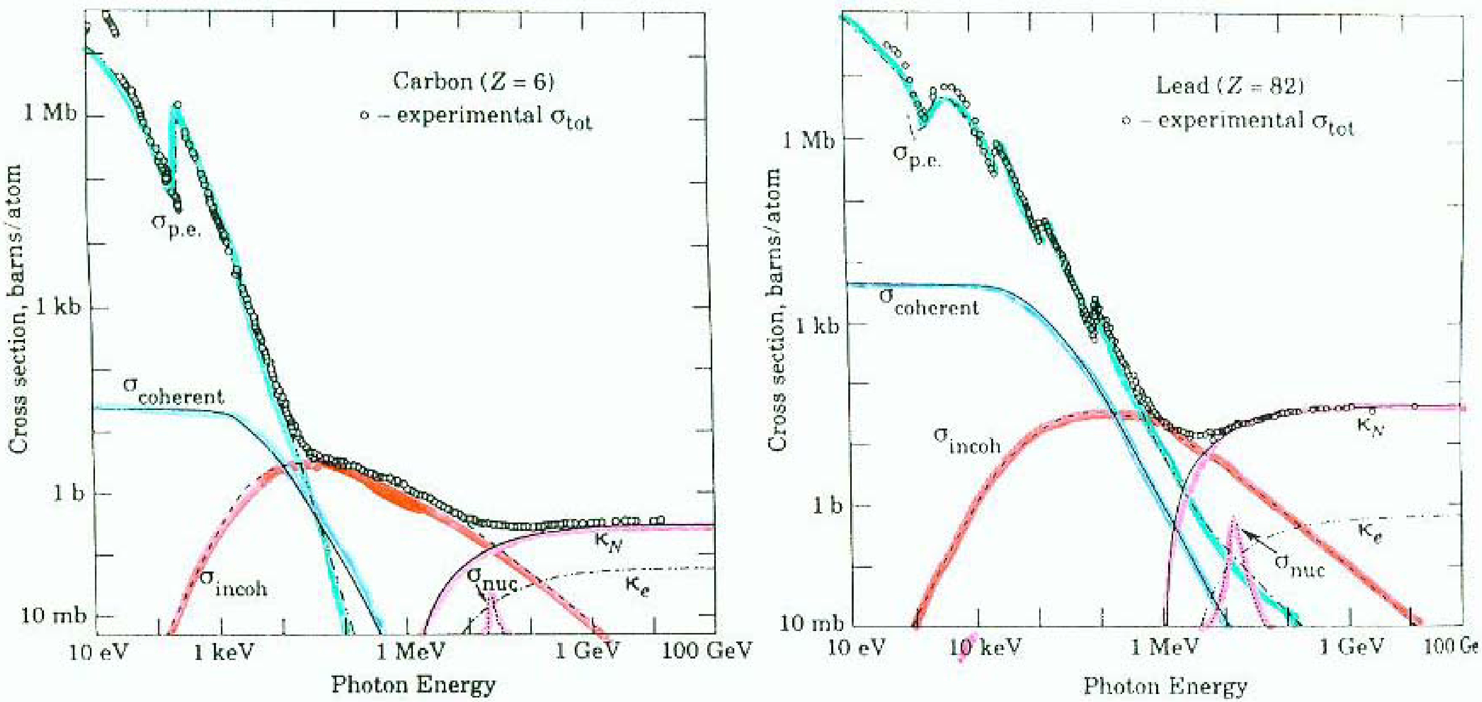


Figure 11.3: Photon total cross sections as a function of energy in carbon and lead, showing the contributions of different processes.

$\sigma_{p.e.}$ = Atomic photo-effect (electron ejection, photon absorption)

$\sigma_{coherent}$ = Coherent scattering (Rayleigh scattering—atom neither ionized nor excited)

$\sigma_{incoherent}$ = Incoherent scattering (Compton scattering off an electron)

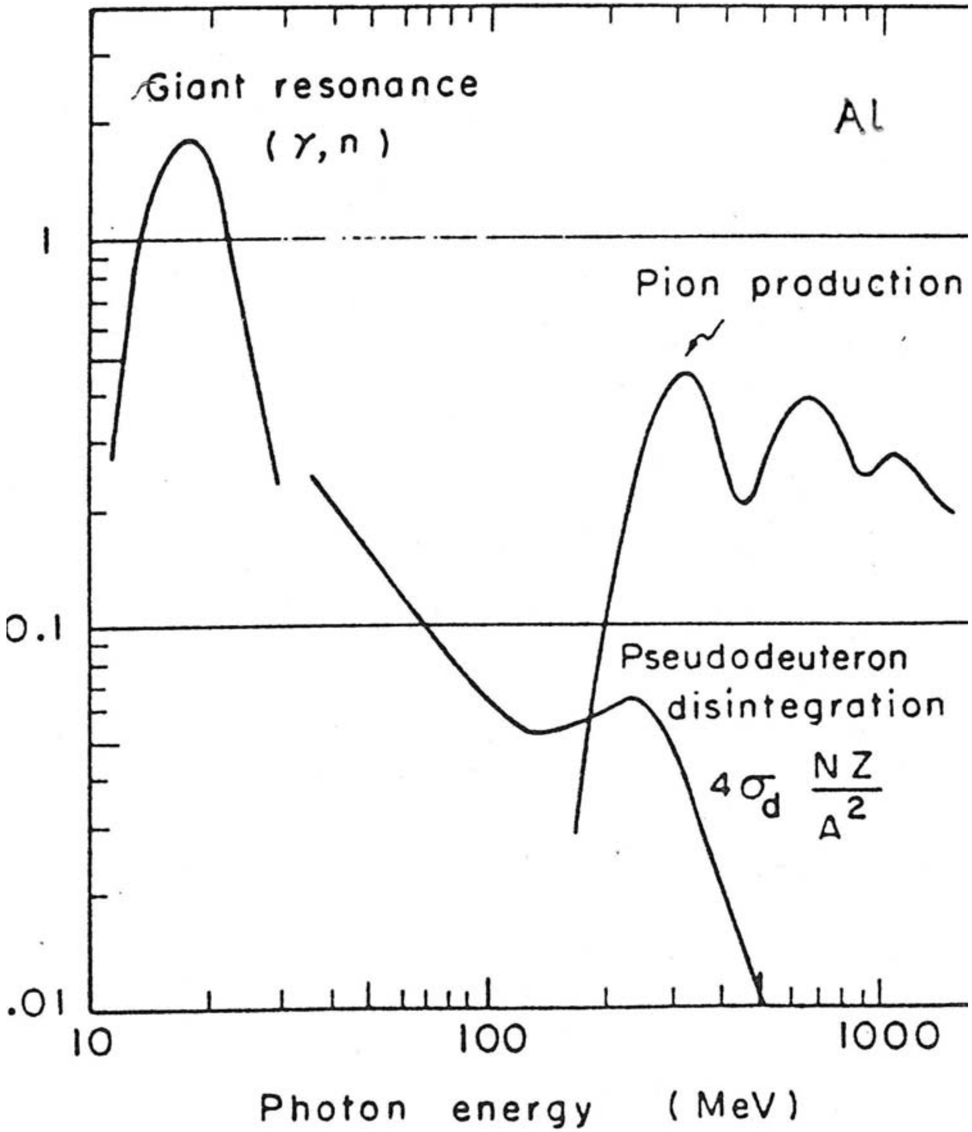
κ_n = Pair production, nuclear field

κ_e = Pair production, electron field

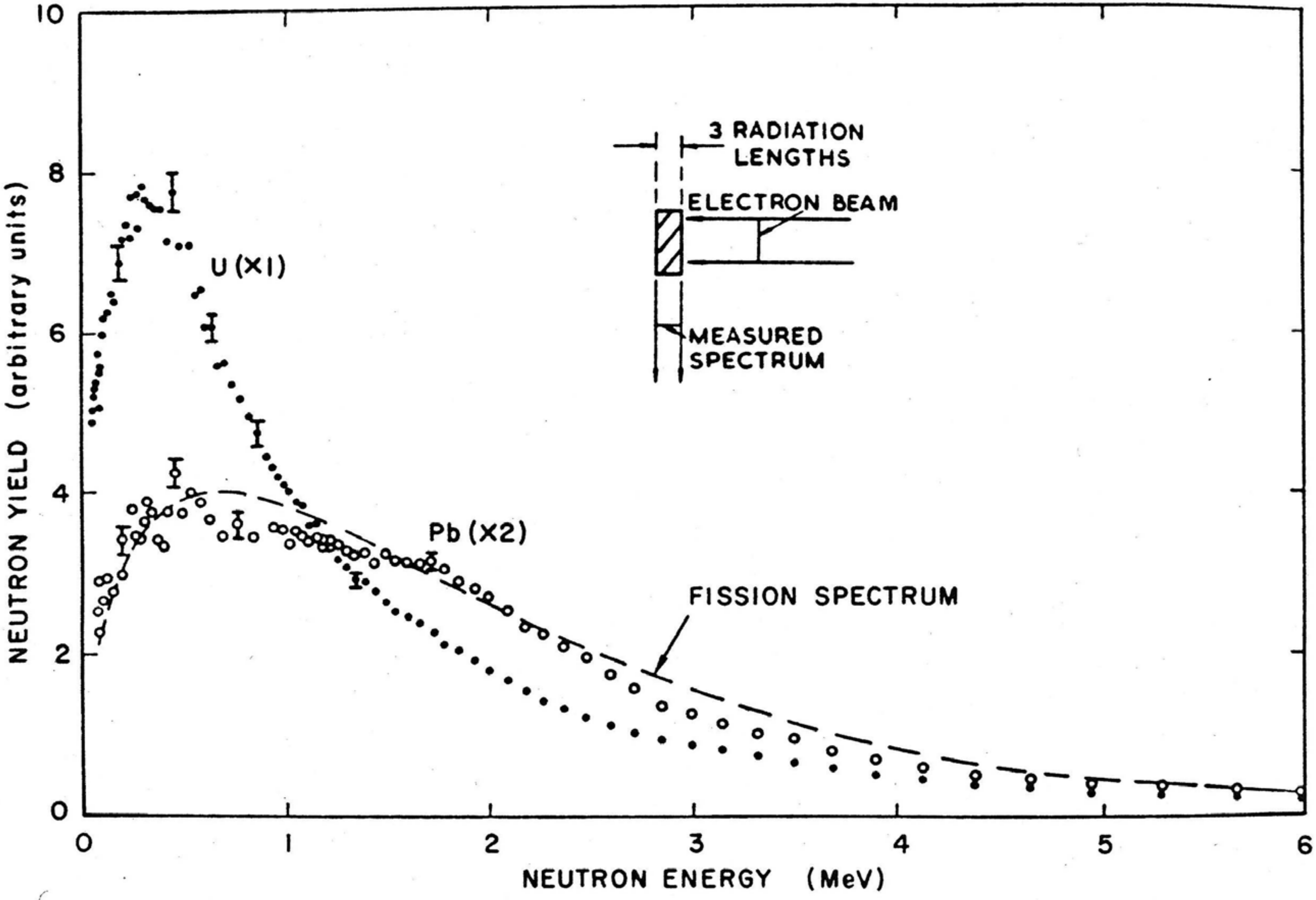
σ_{nuc} = Photonuclear absorption (nuclear absorption, usually followed by emission of a neutron or other particle)

From Hubbell, Gimm, and Øverbø, J. Phys. Chem. Ref. Data 9, 1023 (80). The photon total cross section is assumed approximately flat at least two decades beyond the energy range shown. Figures courtesy J.H. Hubbell.

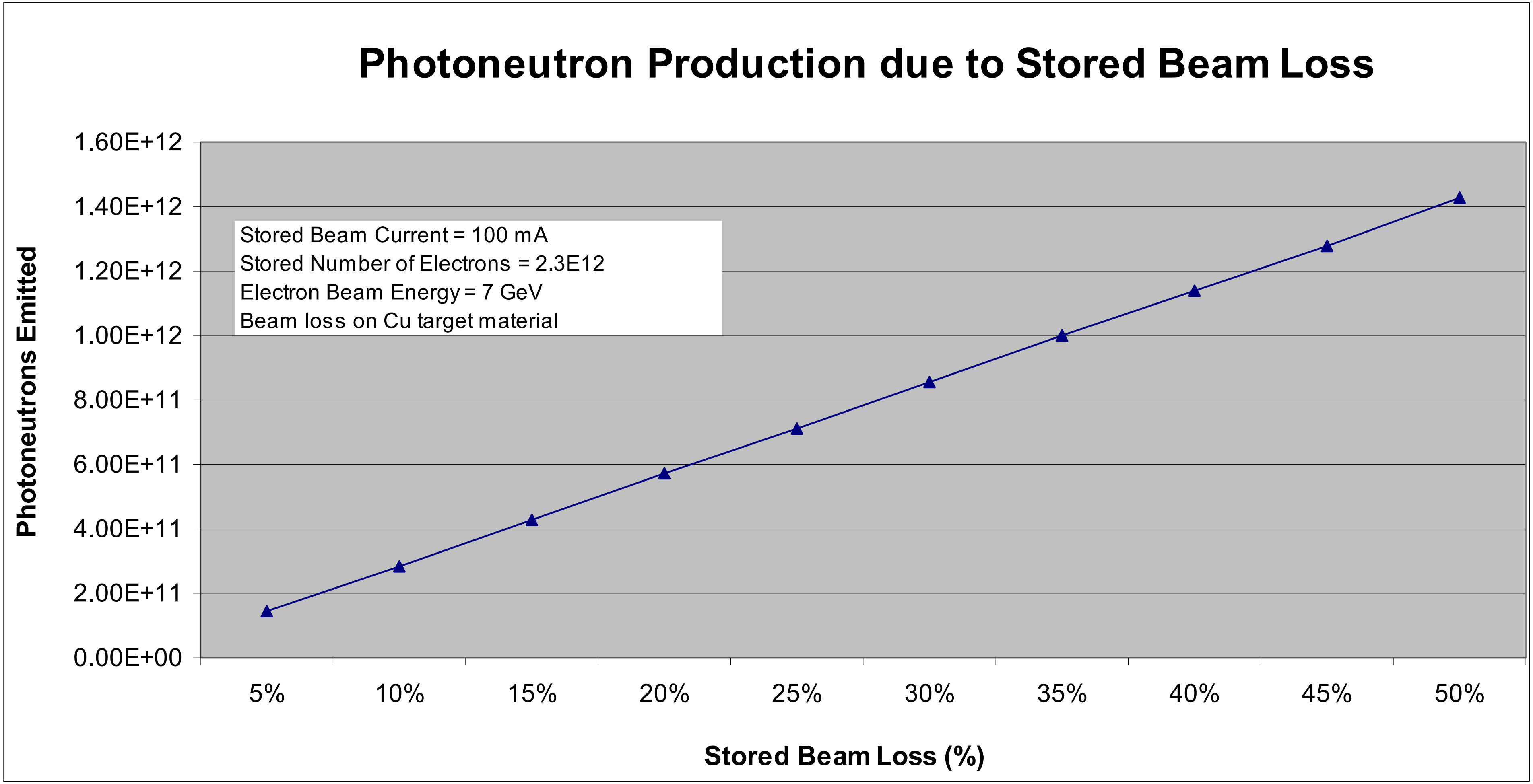
Photoneutron Production Cross Section in Al



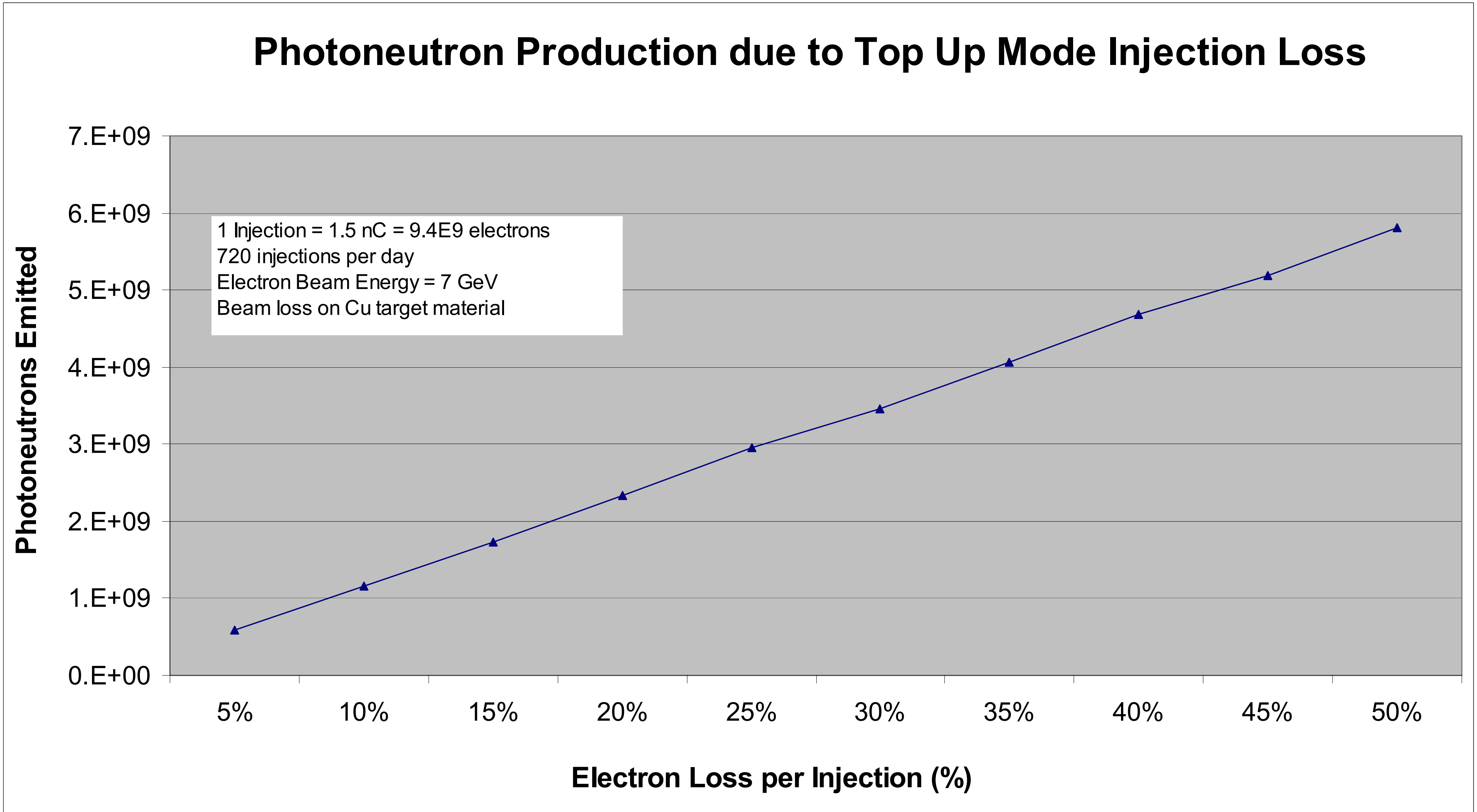
Photoneutron Spectra by 45 MeV Electrons from Target Materials



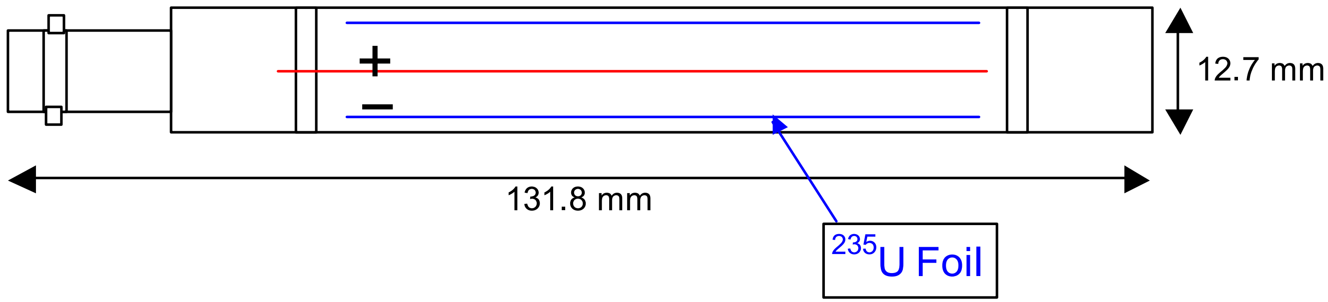
Photoneutron Production as a Function of the Stored Beam Loss on a Copper Target



Photoneutron Production as a Function of the TopUp Mode Injection Beam Loss

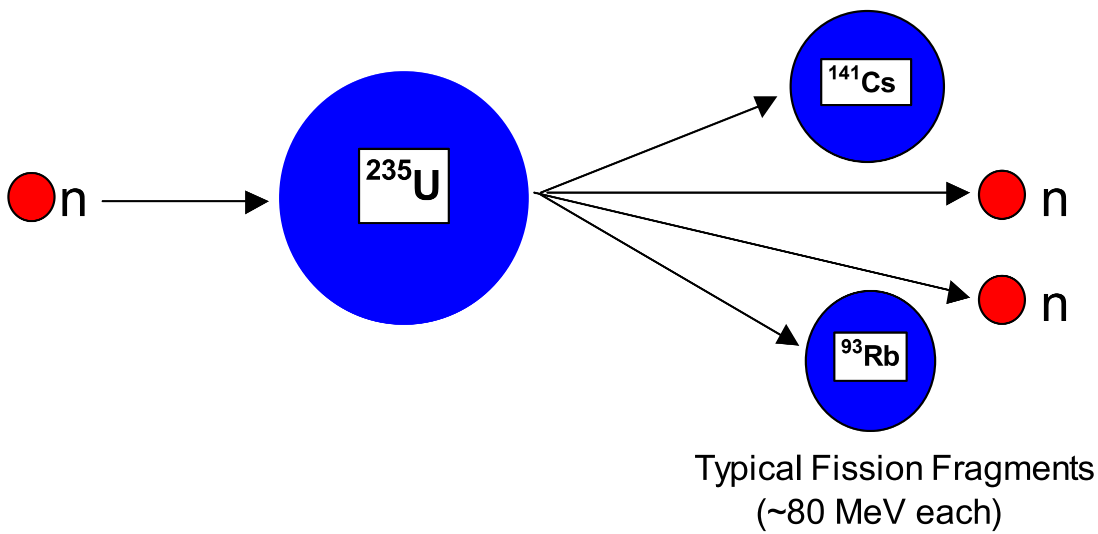


Schematic Diagram of the Fission Detector



Typical Neutron-Induced Fission Reaction

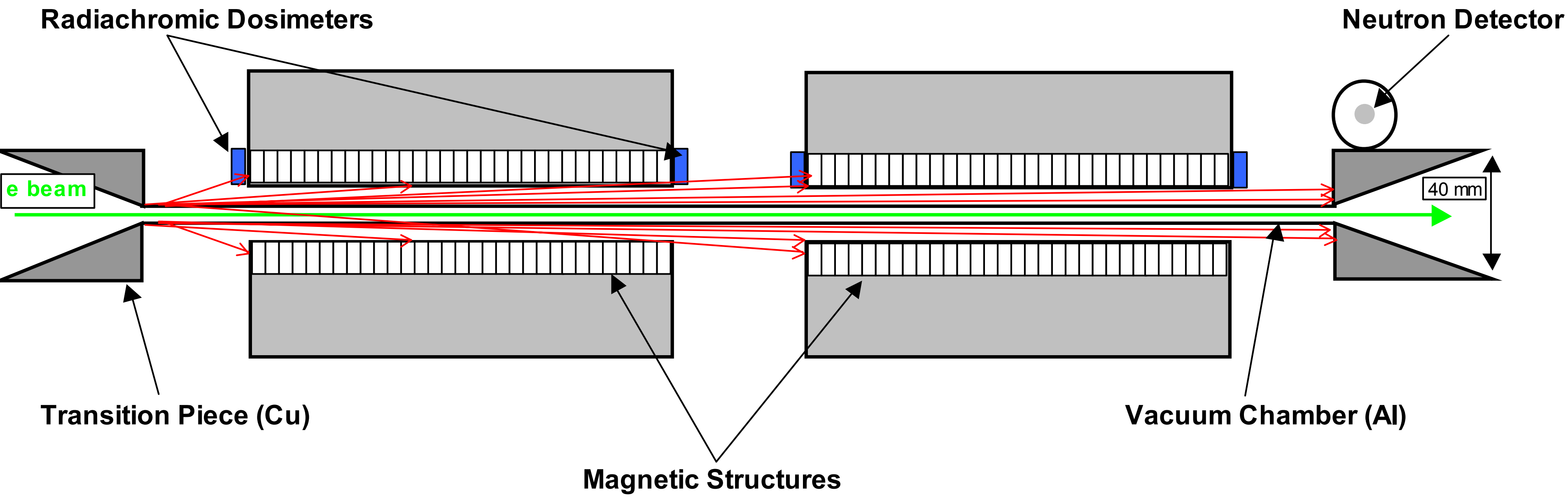
$$^{235}U + n \longrightarrow {}^{93}Rb + {}^{141}Cs + 2n$$



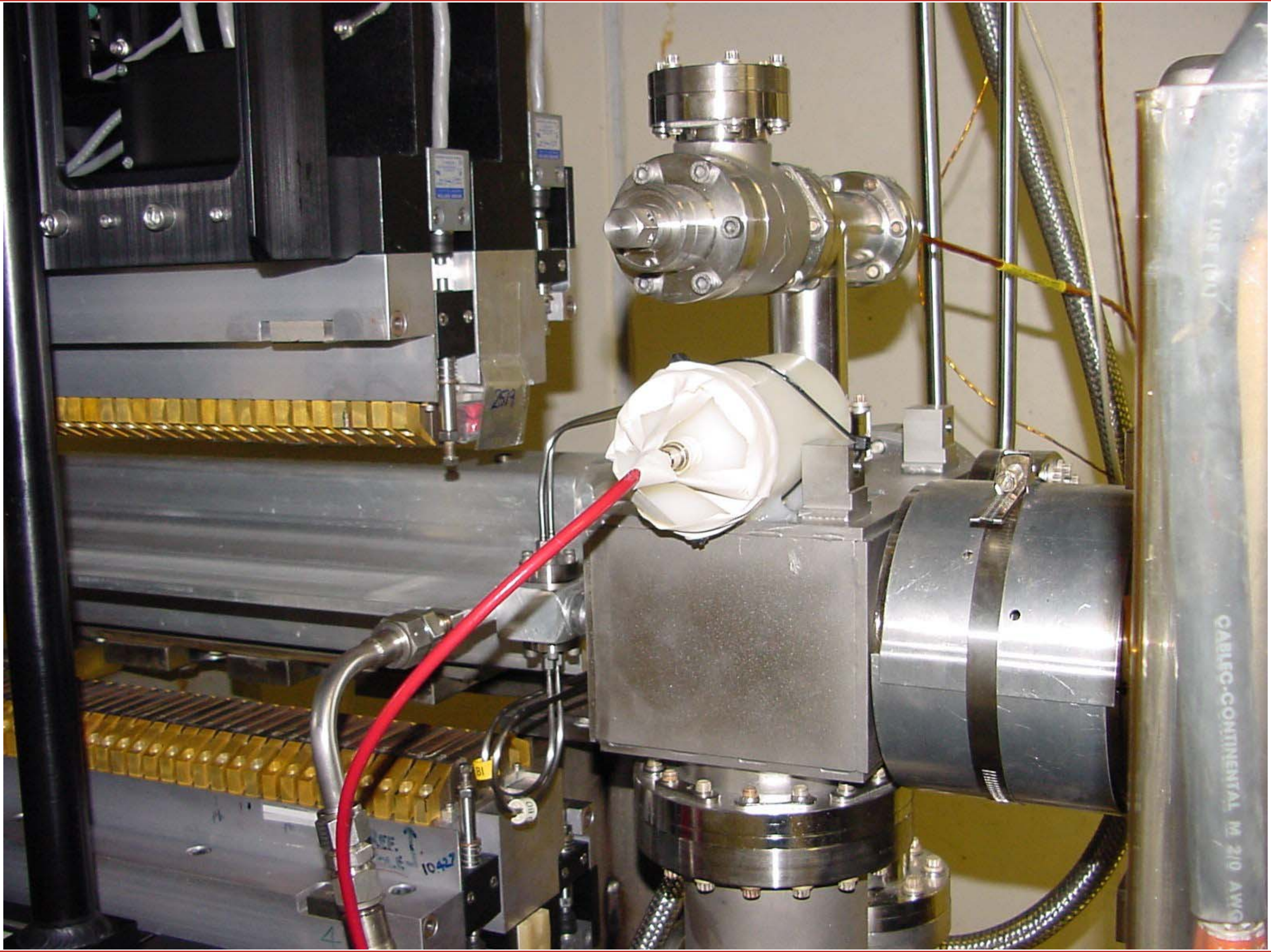
Fission Cross Section of Uranium Isotopes (^{235}U and ^{238}U)

Particle / Radiation	Energy	Cross Section (barns) ^{235}U	^{238}U
Thermal Neutrons	~25 meV	582 b	0.0 b
Fast Neutrons	~1-2 MeV	1.2 b	0.6 b
Photons	>5.3 MeV	3-30 mb	3-30 mb

Beam Loss Scenario in the Insertion Device Straight Sections



Neutron Detector Placement Inside the APS Storage Ring

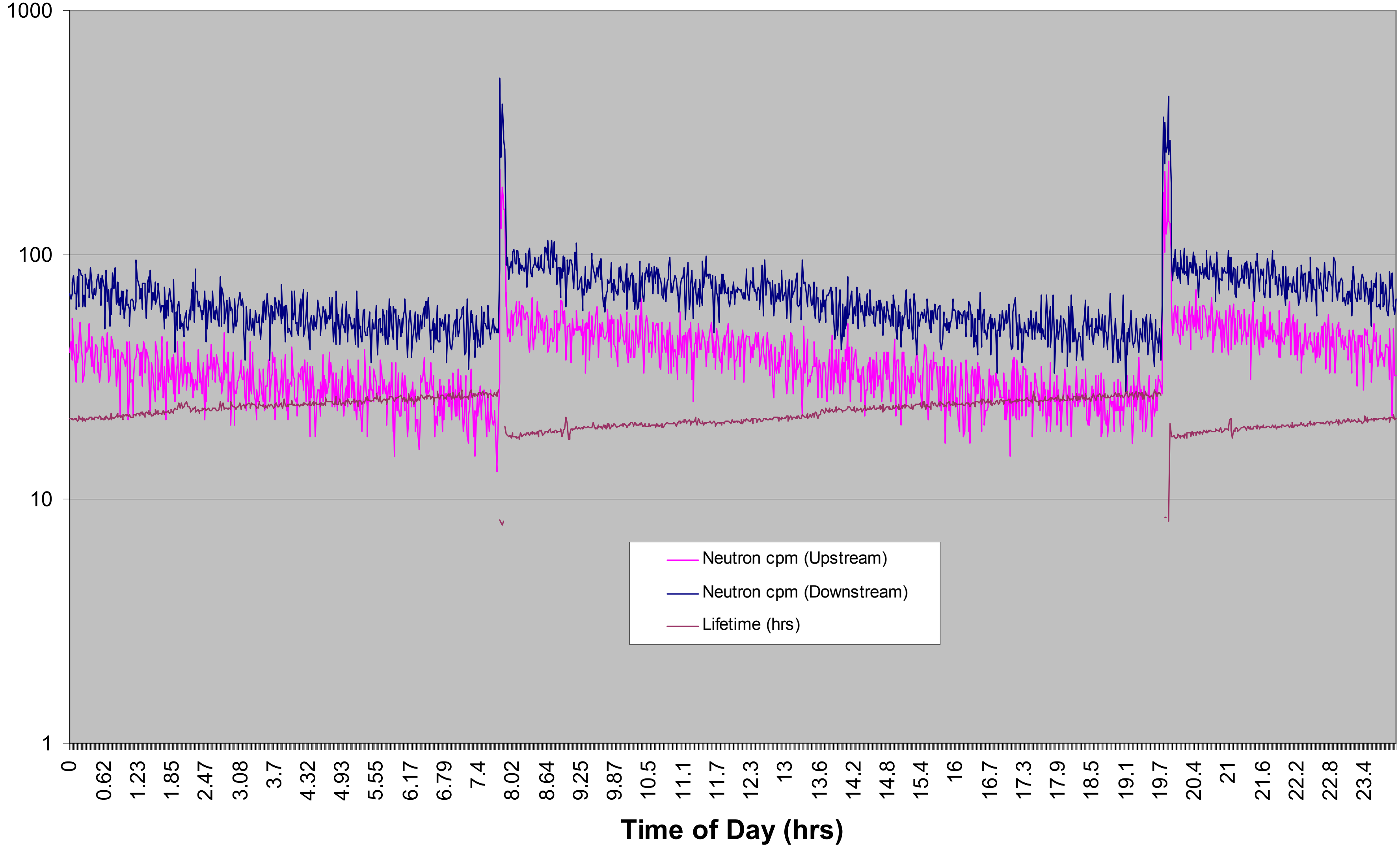


Calibration of the Fission Detector with ^{252}Cf Neutron Source Spectrum

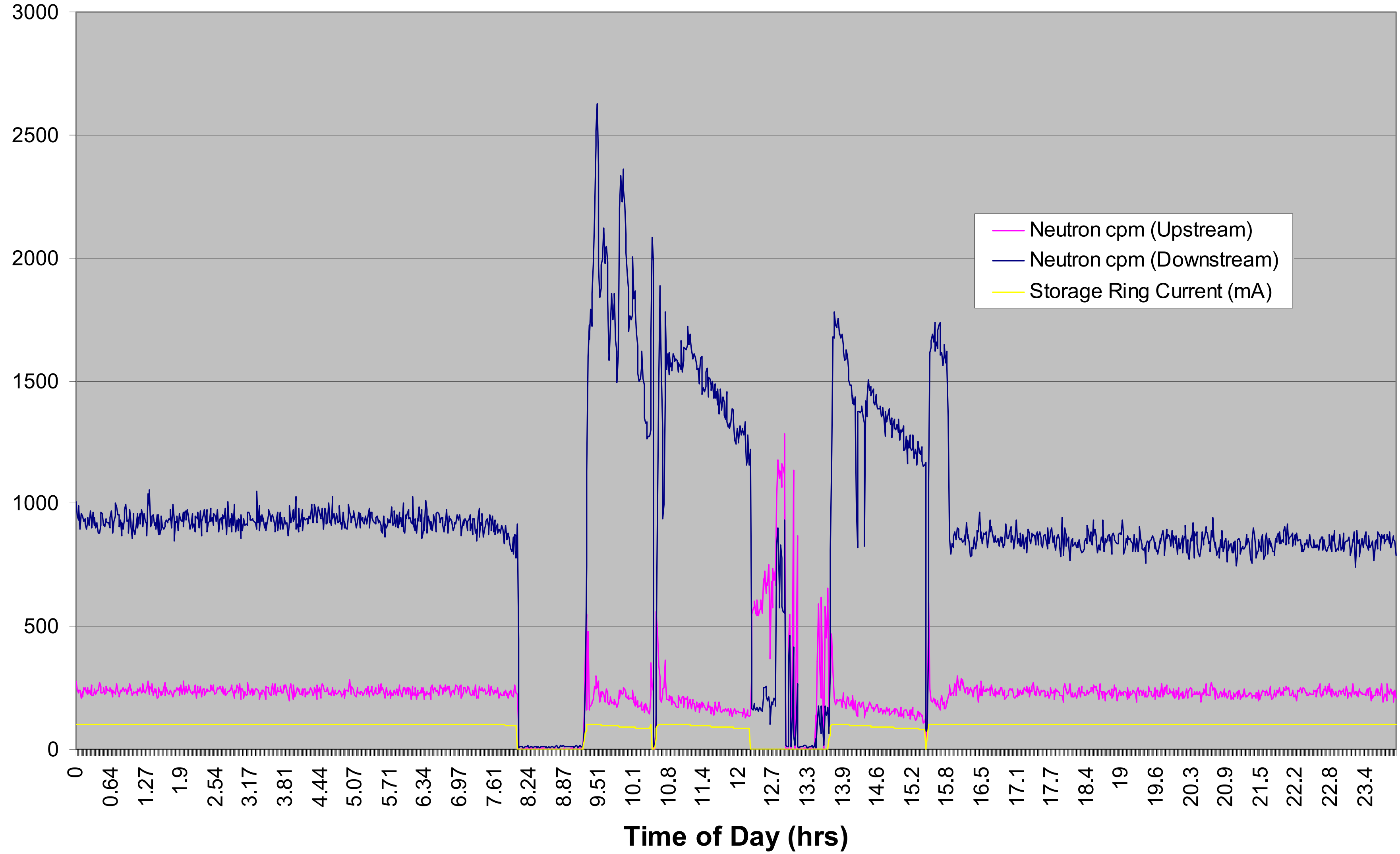
- Measure count-to-flux conversion factors for the detector-moderator configuration

- Optimize the moderator thickness to maximize detector efficiency

Neutron Count Rate vs. Lifetime



Neutron Count Rate vs. Operating Mode



Storage Ring Lifetime vs. Neutron Flux

Lifetime (h)	Emittance	TopUp	Neutron (cpm)	Neutron Flux ($n/cm^2/s$)
10.5	High	No	827	1.1E+04
10.8	Low	Yes	881	1.2E+04
13.5	High	No	597	8.0E+03
18	High	No	527	7.1E+03
21	High	No	278	3.7E+03
22	High	No	166	2.2E+03

Summary

- Fission Detectors provide essential discrimination between photons and neutrons in a high gamma background
- With proper calibration, they can provide valuable information on photoneutron fluence within the accelerator tunnel
- They also monitor neutron doses in terms of neutron-induced damage of radiation sensitive equipment within the storage ring